Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 48 (2014) 1188 – 1193

Energy Procedia

SHC 2013, International Conference on Solar Heating and Cooling for Buildings and Industry
September 23-25, 2013, Freiburg, Germany

Manufacture of malt and beer with low temperature solar process heat

Franz Mauthner[a], Matthäus Hubmann[a], Christoph Brunner[a], Christian Fink[a,]*

[a]*AEE – Institute for Sustainable Technologies, Feldgasse 19, 8200 Gleisdorf, Austria*

Abstract

The manufacture of malt and beer requires large amounts of electrical and thermal energy which is nowadays mainly based on fossil fuels. In State of the Art breweries 7.5–11.5 kWh_{el} [1] and 16.7–33.3 kWh_{th} [1, 2] per hl of beer are needed (reference: final energy demand) and the annual output of medium to large sized breweries may easily exceed one million hl. The entire process heat demand of the thermally driven processes in breweries and malting plants can be met with heat at a temperature of between 25 and 105°C on process level [3, 4]. This enables the integration of solar thermal energy supplied by conventional, non-concentrating solar thermal collector technologies such as flat-plate or evacuated tube collectors. In fact, providing thermal energy by means of solar thermal systems is mostly energy efficient if the energy from the sun is converted into heat and supplied to the process at minimum required temperature level (referred to as solar integration on process level). With this regard and in the framework of a European Union-funded demonstration project, three large-scale solar thermal systems (each with an installed thermal peak capacity ≥ 1 MW_{th}) are being realized. The focus of the project is to demonstrate the integration of large scale solar thermal systems on process level for different applications (mashing, pasteurization of beer, drying of green malt) at process temperatures below 80°C. This script mainly focuses on technical solutions for the hydraulic integration of large solar process heat applications equipped with flat plate collectors for a direct heat supply to thermally driven processes in the brewing industry.

Keywords: solar process heat, solar heat integration in industry, large scale solar thermal system, manufacture of malt and beer

* Corresponding author. Tel.: +43-3112-5886-223; fax: +43-3112-5886-0
E-mail address: f.mauthner@aee.at

doi:10.1016/j.egypro.2014.02.134

1. Introduction

All thermally driven processes in malting plants and breweries require heat at a temperature on process level of between 25 and 105°C (cf. Fig. 1). In an exergetic point of view it appears feasible to supply this heat at a temperature level not higher than absolutely required for a certain process whereas in reality the design of the main heat supply system is often determined by the process heat consumer which demands the highest temperature. In order to reduce exergy losses and fossil fuel based CO_2 emissions full exploitation of available heat recovery potential, the cascade use of thermal energy as well as the integration of renewable heat supply technologies is necessary.

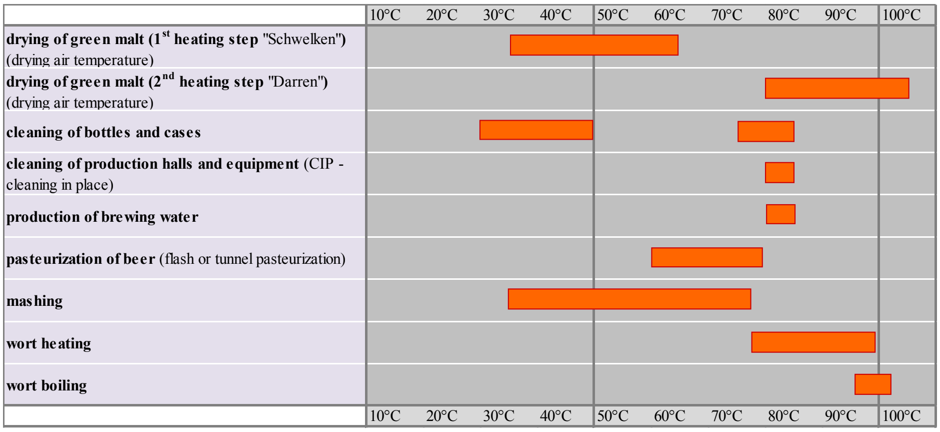

Fig. 1. Thermal processes and associated process temperatures in malting plants and breweries [data source: 3, 4]

From theoretical investigations it is known that with optimized heat recovery and the energetic utilization of organic matter from brewing residues (spent grains) and waste water modern breweries can potentially supply its thermal energy demand over own resources (excluding space heating) [2]. By now this theoretical potential is not fully utilized and hence the remaining energy demand is met by conventional means. Nevertheless a conversion from conventional energy supply systems to energy supply systems based on renewable energies (sun, wind, biomass, geothermal) and production residues (spent grains, waste water) may enable a 100% CO_2 neutral beer production process in the long run.

Considering that increasing the overall energy efficiency of a production process has the highest priority, especially the integration of solar thermal energy supplied by conventional, non-concentrating solar thermal collector technologies such as flat-plate or evacuated tube collectors appears to be a promising alternative to meet remaining low temperature process heat demand in breweries and malting plants already in the short run. With this regard technical solutions for a proper hydraulic integration of solar heat to industry are needed and a successful demonstration of such systems is important for a broader market penetration.

2. Demonstration of the manufacture of beer and malt with low temperature solar process heat

In the framework of a European demonstration project, three large-scale solar process heat applications are being realized for the brewing industry. The focus of the project is to demonstrate the techno-economic feasibility of the integration of large scale solar thermal systems on process level for different applications (drying of green malt, mashing and pasteurization of beer) at process temperatures of below 80°C.

The project is coordinated by the Austrian research institute AEE INTEC and funded by an EU FP7 project (SolarBrew – Solar Brewing the Future – FP7 project no. 295660). The three sites which are brewery Goess in Austria, brewery Valencia in Spain and malting plant Vialonga in Portugal belong to the Heineken Group (Heineken Supply Chain B.V.). In order to meet the holistic approach, the consortium is complemented by a process engineering partner (GEA Brewery Systems GmbH) as well as by the Danish solar thermal collector manufacturer and turn-key supplier of large-scale solar thermal systems Sunmark A/S.

In Table 1 next the basic information of the solar thermal system in the brewery Goess as already built as well as the latest approved design parameters for the two other demonstrators in Valencia and Vialonga are highlighted.

Table 1. Basic information on the three demonstrators (being) realized in the framework of the project SolarBrew

SITE	Country	Collector area[1] [m²]	Peak Power [$MW_{p,th}$]	Process supplied (process temperature) [°C]	Expected solar yield[2] [kWh/(m²•a)]	Solar fraction[3] [%]	Irradiation onto horizontal plane [kWh/(m²•a)]
Brewery Goess (built)	AT	1,375	1.0	mashing (58-78)	280	approx. 30%	1,070
Brewery Valencia (design freeze)	ES	1,485	1.0	pasteurization of beer (63-65)	630	approx. 45%	1,610
Malting plant Vialonga (design freeze)	PT	4,331	3.0	drying of green malt (35-55)	720	approx. 20%	1,690
Total		7,191	5.0				

1 Reference: aperture area (13.75m² / 15.0m² aperture/gross area per collector)

2 Simulations results based on measured load profiles

3 Solar fraction with regard to the respective process supplied with solar thermal energy

2.1. Solar assisted mashing process for the brewery Goess

The solar thermal system designed for the brewery Goess, Austria was commissioned in June 2013 and implies several innovative approaches: Two steam supplied vessels (mash tuns) were retrofitted by especially designed internal plate heat exchanger templates which enable a supply system based on hot water instead of steam. The new hot water supply is fed by waste heat from a nearby biomass CHP plant as well as by a large scale ground mounted solar thermal system (100 collectors summing up to a total of 1,500 m² gross collector area) which is hydraulically connected to a 200 m³ pressurized solar energy storage tank. Fig. 2 next schematically shows the hydraulic integration of the new hot water supply system to the retrofitted mash tuns.

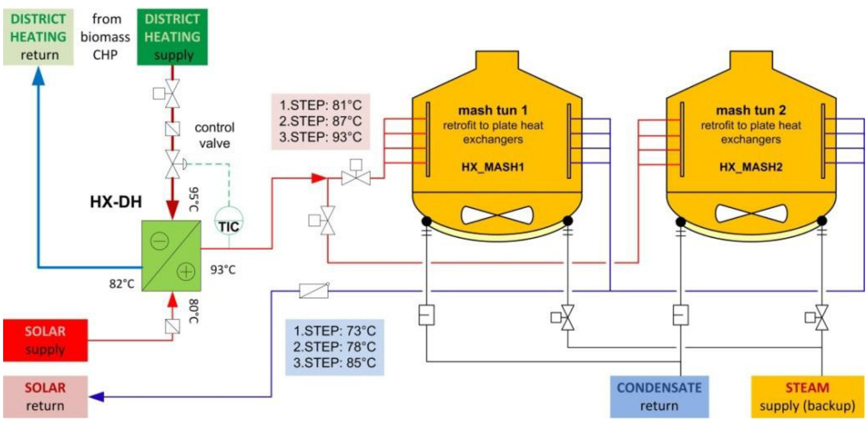

Fig. 2. Schematic diagram of the retrofitted solar + biomass based hot water supply system for the mashing process in the brewery Goess

While mashing the temperature of the mash is continuously increased from a starting temperature of around 58°C to a final temperature of around 78°. If there is solar thermal energy at the right temperature available the energy is taken out from the solar energy storage tank and pumped to the retrofitted plate heat exchangers. The return flow from the process back to the storage is stratified according to the temperature. If the temperature in the solar energy storage is not high enough but at least some °C higher than the process return temperature the process supply temperature needed is heated up in-line via the waste heat from the biomass CHP plant. In case the temperature in the energy storage tank is lower than the process return flow temperature the storage is bypassed and the mash tuns are fed by waste heat only. In case both systems cannot supply either the temperature or the energy quantity needed the existing steam supply system acts as backup in parallel.

From simulations it can be expected that almost 30% of the thermal process energy demand for mashing can be supplied by the solar thermal system in future and that the entire process energy demand will be covered with renewable sources only (waste heat from biomass + solar thermal). In sum round 1,570 MWh of natural gas per year (considering a utilization rate of the existing natural gas fired steam supply system of 85%) which corresponding to round 38,000 tons of CO_2 equivalents per year (based on GEMIS database) can be saved in future by this hybrid system.

2.2. Solar assisted pasteurization of beer in the brewery Valencia

In Valencia, Spain a solar thermal system supplying heat to a tunnel pasteurizer will be put into operation by spring 2014.

In sum 108 large-area flat plate collectors (1,620 m² gross collector area) will be mounted on ground and hydraulically connected to an atmospheric solar energy storage tank with a water volume of 350 m³. The energy from the sun will be used to supply a tunnel pasteurizer for the pasteurization of canned beer with hot water at a temperature of 85°C which also means that the existing steam based supply system is going to be significantly changed. In Fig. 3 the modification of the steam based system (Fig. 3, left) to a system with serial solar hot water preheating (Fig. 3, right) is shown schematically.

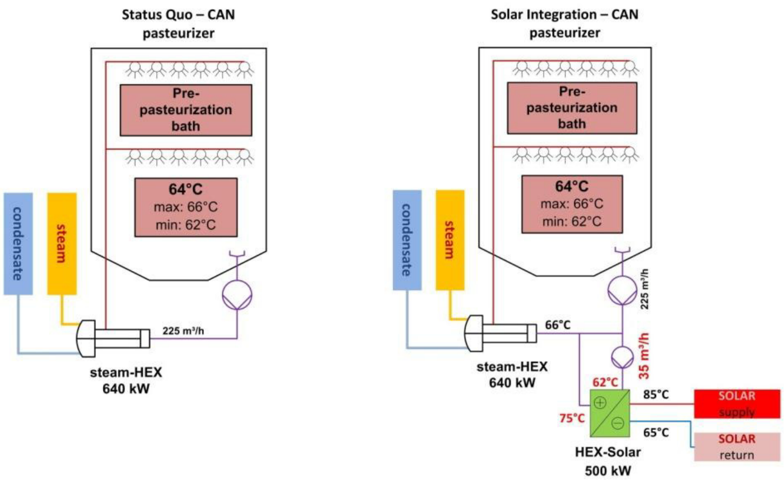

Fig. 3. Schematic diagram of the steam heated sprayer loop in the existing can tunnel pasteurizer in the brewery Valencia (left) and hydraulic integration of solar hot water with a serial connected plate heat exchanger (right)

Due to the high enthalpy of steam the high mass flow (225 m³/h) of the process supply loop of the existing tunnel pasteurizer can be effectively temperature controlled in a very narrow temperature range of between 2 – 5°K (Fig. 3, left). For a hot water based supply system, especially when fed by solar thermal energy from a storage tank, such narrow temperature spreads would only be possible with high flow rates causing high pressure losses und worst conditions for both solar thermal system operation and the utilization of the energy storage volume. Hence the retrofitted system is designed in a way that only a small bypass stream of 35 m³/h is heated up but to a higher temperature of 75°C resulting in the appropriate mixing temperature after the bypass. The bypass will only be activated if the quantity and quality (temperature) of the energy in the storage is sufficient. Else the existing steam bundle heat exchanger supplies the energy needed.

According to simulation results almost 45% of the thermal process energy demand for the existing can pasteurizing line can be supplied by the solar thermal system in future, replacing 1,100 MWh of natural gas per year (considering a utilization rate of the existing natural gas fired steam supply system of 85%) which corresponds to savings of 26,750 tons of CO_2 equivalents per year (based on GEMIS database).

It has been found in the detail engineering process that this kind of heat integration is very cost effective compared to several other hydraulic configurations also investigated in the course of the project especially in combination with solar thermal heat integration but also if there is in general the intention to combine a steam based supply system in serial with a hot water based supply system.

2.3. Solar assisted drying of green malt in the malting plant Vialonga

In Vialonga, Portugal the largest demonstration system with a total of 315 large-area flat plate collectors (4,725 m² gross collector area) mounted on ground and connected to an atmospheric 400 m³ solar energy storage tank is being commissioned by spring 2014. The energy from the sun will be used to supply the so called drying kiln with hot water at a temperature of around 75-80°C to heat up drying air for drying of green malt. Fig. 4 next shows a schematic diagram of the drying kiln highlighting the cascade energy supply to the drying air including a retrofitted heating step fed by the solar thermal heat (step I: air / air HX, step II: water / air HX from CHP waste heat, step III: retrofitted water / air HX from solar thermal system, step IV: steam / air HX from natural gas steam boiler).

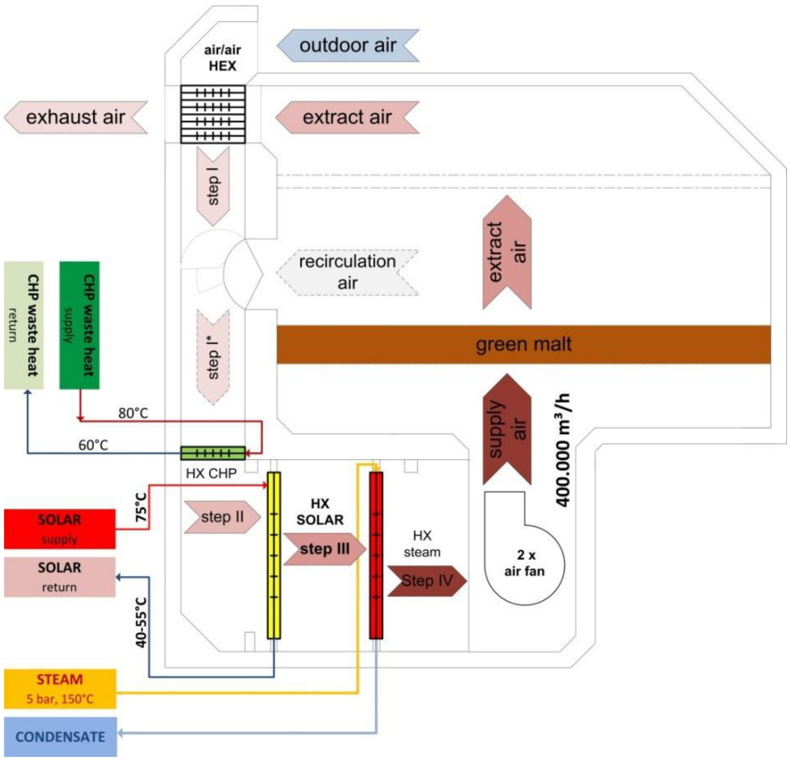

Fig. 4. Schematic diagram of the cascade energy supply of the drying kilt extended by an additional heating step fed by solar thermal heat

The solar thermal integration was designed in a way that the utilization of waste heat from the CHP plant (step II) will not be reduced but natural gas from the steam boiler can be saved (step IV). From simulations it can be expected that around 20% of the thermal process energy demand at present supplied by steam for drying of green malt can be supplied by the solar thermal system in future. This savings correspond to 3,670 MWh of natural gas (considering a utilization rate of the existing natural gas fired steam supply system of 85%) resp. to round 89,000 tons of CO_2 equivalents per year (based on GEMIS database).

In this demonstration project the cascade supply of heat at appropriate temperature levels and with different supply technologies provides a very good example for an exergy optimized industrial process with high potential for the efficient integration of waste heat and solar thermal energy.

Acknowledgements

We especially thank all project partners (Heineken Supply Chain B.V., GEA Brewery Systems GmbH and Sunmark A/S) for the fruitful collaboration. We appreciate the financial support from the European Commission (FP7) as well as the co-financing by the Austrian Klima- und Energiefonds.

References

[1] Scheller L. Integration of solar process heat in the brewing industry. Brau Beviale 2012 (unpublished sources by GEA Brewery Systems GmbH; presentation in German language)

[2] Muster-Slawitsch B, Weiss W, Schnitzer H, Brunner B. The green brewery concept - Energy efficiency and the use of renewable energy sources in breweries. Applied Thermal Engineering 31 (2011) 2123-2134

[3] Herzog U. Possibilities for the use of „Emerging Technologies“ in the food industry for reduced thermal energy consumption and solar thermal heat integration. Pinkafeld 2011 (master thesis in German language)

[4] Kunze W. Technology of Malting and Brewing (in German language), 9th ed. Versuchs- und Lehranstalt für Brauerei in Berlin, Berlin, Germany, 2007